DEBARKING OF TEAK *TECTONA GRANDIS* LINN. F. BY GAUR *BOS GAURUS* H. SMITH DURING SUMMER IN A TROPICAL DRY DECIDUOUS HABITAT OF CENTRAL INDIA[1]

M.K.S. Pasha, G. Areendran, K. Sankar and Qamar Qureshi[2]

Key words: Food habits, debarking, gaur, *Bos gaurus*, Madhya Pradesh, teak, *Tectona grandis*, bark feeding

Debarking of teak trees *Tectona grandis* Linn. f. by gaur *Bos gaurus* H. Smith was studied during the summer of 1996 in the Pench Tiger Reserve, Madhya Pradesh. Seven one-hectare vegetation plots were sampled within the summer ranging areas of the gaur to quantify and determine the extent of debarking. Of the sampled trees, 39% were debarked, 73% of which had low level of debarking. The teak trees of different girth classes were not debarked in proportion to their availability. No mortality was observed amongst the debarked trees. A maximum of 26.6% crude protein was recorded from the bark samples. Amongst the minerals found in the teak bark, calcium was the major constituent, followed by sodium, iron, manganese and copper. Of the food plants eaten by the gaur, teak bark was consumed most (14%). The moisture content in the teak bark varied from 25 to 80%. Consumption of the high protein, calcium- and potassium-rich teak bark would be beneficial to the gaur especially during the dry months when food resources are limited. Further analysis of the bark samples of teak and other food plants of the gaur, for secondary compounds and nutritional quality, would enable a better understanding of the debarking behaviour of the gaur.

Introduction

The selection of food plants by herbivores could be due to the presence of soluble carbohydrates, proteins, plant fibre, minerals, vitamins, secondary compounds and organic acids (Westoby 1978). To obtain these nutrients, the animals consume different parts of the plants like leaves, twigs, roots, floral parts and bark. Bark feeding is a well-known phenomenon among groups of mammals such as rodents, lagomorphs, ungulates, proboscides and primates (Curtis 1941, McKay 1973, Laws *et al.* 1975, Vancuylenberg 1977, Sullivan and Sullivan 1982, Prior 1984, Kenward and Parish 1986, Borges 1989, Sukumar 1989, Joshua 1992, Sharma and Prasad 1992, and Khan *et al.* 1994).

The existing information on the debarking habits of gaur (*Bos gaurus*) is so far mainly anecdotal. The gaur is known to feed on the bark of *Adina cordifolia* (Brander 1923, Schaller 1967), *Holarrhena antidysentrica* (Ogilive 1954), *Tectona grandis* (Ranjitsinh 1997) and *Wendlandia natoniana* (Ogilive 1954).

Debarking of teak by gaur was studied between April and June 1996 in the Pench Tiger Reserve (PTR), Madhya Pradesh. Only teak trees were debarked by gaur and debarking of teak by other wild ungulates in the study area was not observed.

Study Area

Pench Tiger Reserve, PTR, (78° 55' to 79° 35' E and 21° 8' to 22° N) lies in the southern lower reaches of the Satpura hill range in the southwestern region of Madhya Pradesh. The Reserve with a total area of 757.85 sq. km comprises a wildlife sanctuary, national park and reserved forests.

In addition to gaur, the wild ungulates found in PTR are chital (*Axis axis*), sambar (*Cervus unicolor*), nilgai (*Boselaphus

[1]Accepted December, 2001
[2]Wildlife Institute of India, P.O. Box 18,
Chandrabani, Dehra Dun 248 001, Uttaranchal, India.

tragocamelus), barking deer (*Muntiacus muntjac*), chowsingha (*Tetraceros quadricornis*), chinkara (*Gazella gazella benneti*) and wild pig (*Sus scrofa*). The predators existing in the area are tiger (*Panthera tigris*), leopard (*P. pardus*) and wild dog (*Cuon alpinus*).

The Pench river flows in a north-south direction, dividing the Park into two almost equal halves. Due to the construction of a hydroelectric dam on the Pench river, 54 sq. km of the low-lying area on either side of the river has been submerged. During the summer months the river dries up, resulting in small water bodies which are vital for the survival of the gaur and other wild animals.

Climatically, the area has four seasons: summer (March-June), monsoon (July-August), post monsoon (September-October) and winter (November-February). The temperature ranges from a minimum of -2 °C at the height of winter to a maximum of 49 °C in peak summer. The average annual rainfall is 1,400 mm. The forest cover of the area has been classified as Tropical Dry Deciduous and Tropical Moist Deciduous types (Champion and Seth 1968). The dominant vegetation types include teak forest, teak-miscellaneous forest, miscellaneous forest, *Butea-Zizyphus* mixed woodland, *Anogeissus-Boswellia* mixed forest, *Cliestanthus collinus* forest and riverine forest. The terrain is gently undulating and criss-crossed by small streams, most of which are seasonal. The hills have gradual to steep slopes with almost flat tops. The mean altitude is 550 m.

METHODS

Though teak trees were found all over the Tiger Reserve, they were debarked only in the summer ranges of the gaur, close to Pench river in the National Park. Based on a reconnaissance, seven one-hectare plots in an area of 40 sq. km were randomly selected within the summer ranges of the gaur, along the Pench river in the National Park, to quantify debarking. In each one-hectare plot, nine circular plots of 10 m radius at an interval of 25 m were sampled (n = 63) for the following data:

(a) Total number of trees of all species and their GBH (girth at breast height).

(b) The debarked area of the tree was calculated by taking the average width of the debarked portion at three different points along the debarked strip of the stem and multiplying it with the length of the debarked strip. The product obtained is multiplied with the constant π (3.14). In case of two separate portions debarked on the same tree, the area of each was calculated separately and summed to give the total area.

(c) The area from the base of the stem to the upper tip of the debarked strip was determined as the area available for debarking. This entire portion of the stem was assumed to be cylindrical. The surface area of this cylinder was calculated to obtain the available area (π dh, where: d = diameter of the stem at breast height, h = height from the ground to the tip of the debarked portion and π = constant 3.14).

(d) Extent of debarking (ED) was categorised into three classes, low (< 25% of the available area debarked), medium (25% to 50% of the available area debarked) and high (>50% of the available area debarked) and was calculated using the following formula:

$$ED = \frac{\text{Area Utilized}}{\text{Area Available}} \times 100$$

(e) Height at which debarking occurred from the ground.

The sampled teak trees were grouped into eight different girth classes (<21 cm, 21-40 cm, 41-60 cm, 61-80 cm, 81-100 cm, 101-120 cm, 121-140 cm, 141-180 cm) to analyze the utilization pattern of each girth class. To determine the difference in the expected and observed utilization patterns of different teak girth classes, chi-square goodness of fit test (G) was used (White and Garrot 1990). To test the difference in proportionate use and availability for each girth class, 95% simultaneous confidence interval was calculated following Marcum and Loftsgaarden (1980). Student's t-test (Fowler and Cohen 1986) was used to detect the differences between mean density (trees/ha) of debarked and other food plant (trees) species in the plots sampled.

A total of 180 samples of teak bark representing nine girth classes were collected. The fresh weights of bark samples were taken in the field and then oven dried at 60 °C for 24 hours and weighed again. The difference in the fresh and the dry weight were estimated to determine the percent moisture content in the bark. All bark samples were tested for percent crude protein, ash content and calorific value (Allen 1989). Kjeldahl method (Allen 1989) was used to estimate the nitrogen content in the bark. The values of nitrogen expressed as percentage of dry weight were multiplied by a factor of 6.25 to obtain the percent protein (Cunnif 1995). Percent ash was estimated by combustion of a sample of known weight in a muffle furnace at 600 °C for 6 hours. The residue left after the combustion of organic matter in the sample, is the ash content for that species. The calorific value of the bark was estimated to get the gross energy (kcal/g) by igniting them in a Gallenkamp Ballistic Bomb Calorimeter. One bark sample representing the different girth classes was taken for the analysis of the minerals. The dried and ground samples were digested by the Mixed Acid Digestion Method and were analysed for calcium, copper, manganese and iron. Inductive Couple Plasma Emission Spectrophotometer (ICPS) was used for the analysis of the minerals (Allen 1989).

Data on the food habits of gaur was collected by opportunistic sightings. In total, 130 feeding observations were recorded. The food plant species and parts eaten were noted down for each observation. A total of 50 individuals of teak were tagged to monitor the mortality, if any, due to debarking by gaur.

RESULTS

The teak trees were virtually leafless at the time when debarking was observed. Except calves, individuals of all age groups were observed feeding on the teak bark. Direct feeding observations (n = 130) showed that browse formed a major proportion of the diet of the gaur during summer (grass: browse ratio 1: 3). A total of 11 tree, 3 shrub, 3 climber, 4 grass and 1 herb species were recorded as summer food plants of the gaur (Table 1). Among the plant parts eaten by gaur, teak bark was the most frequent (14%).

TABLE 1

FOOD PLANTS OF GAUR IN PENCH TIGER RESERVE (SUMMER 1996)

Plant forms	Plant parts	% Observations (n=130)
Trees		
Ougenia dalbergioides	L	10.0
Tectona grandis	B	14.0
Diospyros melanoxylon	L	6.0
Bauhinia racemosa	L	1.0
Grewia tiliaefolia	L, FL	3.0
Flacourtia ramontchii	L	1.5
Miliusa velutina	L	1.5
Aegle marmelos	L, FR	3.0
Bridelia retusa	L	6.0
Cordia myxa	L	1.5
Zizyphus xylopyra	L	2.0
Shrubs		
Grewia hirsuta	L, FL, FR	11.0
Barleria spp.	L	1.5
Helicteres isora	L	2.0
Climbers		
Ventilago madraspatana	L, FR	2.0
Bauhinia vahlii	L	6.0
Acacia pennata	L	0.7
Grasses		
Dendrocalamus strictus	L, SD	9.0
Cynodon dactylon	L	3.0
Heteropogon contortus	L	10.0
Herbs		
Sida spp.	L, FL, FR	2.0

(L = Leaf, FL = Flower, FR = Fruit, SD = Seed, B = Bark)

Of the 630 teak trees enumerated during the sampling, 247 were found debarked. The debarking by gaur among the eight girth classes of teak trees showed a significantly different ($G=67.3$, $df=7$, $p< 0.001$) utilization pattern (Table 2). The Simultaneous Confidence Interval identified girth class III (41-60 cm) as preferred, girth class II (21-40 cm) as avoided, and the trees of other girth classes used in proportion to their availability.

The mean density (trees/ha) of teak trees was high in debarked plots (Table 3) as compared to plots where debarking was absent ($t = 365.4$, d.f. $= 61$, $p< 0.0001$), whereas the mean density (trees/ha) of food plants (trees) of gaur in the debarked plots was significantly lower than that in the undebarked plots ($t = 540.3$, d.f. $= 61$, $p < 0.0001$).

The height at which gaur debarked the tree varied from 37.4 to 78.8 cm (average 69.2 cm). Of the total teak trees sampled, 39.2 % trees were debarked. The levels of debarking varied between girth classes. Of the total trees debarked (n=247), 73% were in the low, 21% in medium and 6% in high debarking category.

The estimated calorific value and the percent ash content in teak bark ranged from 3.1 to 4.3 kcal/gm and 8.8 to 16.4 % respectively. The percent crude protein varied between 7.7 and 26.6 %. The results of the analysis of the minerals in the bark are given in Table 4.

The water content among the nine girth classes varied from 25% to 80%. The mean water content estimated was 46.22% (SE ±9.01).

DISCUSSION

Several arguments have been put forth to explain the probable reason of debarking behaviour in the different species of mammals. The mammals may debark in response to shortage of food resource in an area (MacKinnon 1976), or shortage of mineral and trace elements required to meet their nutritional demand (Allen 1943, Bax and Sheldrik 1963, Croze 1974 and Vancuylenberg 1977), or for maintaining an optimum fibre: protein ratio for proper digestion of food and better assimilation of nutrients (Spinage 1994).

As the summer advances, most of the herbaceous layer in PTR dries up, resulting in poor quality of such resources. As a result, the gaur may turn to the available browse species and fibrous teak bark. In dry seasons, high fibrous diet increases the digestive efficiency by increasing the retention time of the food in the gut (Owen-Smith 1988) and also by decreasing the turnover rate of the rumen content (Bell

TABLE 2
PREFERENCE RATING OF DEBARKED TEAK TREES BY GAUR IN PENCH TIGER RESERVE

Class	GBH class	P_1	P_2	Confidence limits	R
I	<21	0.156	0.109	$-0.085\ P_1 = P_2\ 0.178$	0
II	21-40	0.580	0.356	$0.115\ P_1 > P_2\ 0.332$	-
III	41-60	0.126	0.275	$-0.271\ P_1 \leq P_2\ -0.028$	+
IV	61-80	0.053	0.069	$-0.152\ P_1 = P_2\ 0.1194$	0
V	81-100	0.046	0.093	$-0.181\ P_1 = P_2\ 0.087$	0
VI	101-120	0.024	0.073	$-0.185\ P_1 = P_2\ 0.087$	0
VII	121-140	0.008	0.012	$-0.144\ P_1 = P_2\ 0.135$	0
VIII	141-180	0.009	0.012	$-0.143\ P_1 = P_2\ 0.136$	0
n		931	247		

($G = 67.31$, d.f. $= 7$, $p<0.0001$)
P_1 = proportions available, P_2 = proportions utilized; n = number of trees in available and utilized categories; R = preference rating; (-) utilized less in proportion to its availability; (+) = utilized more in proportion to its availability; (0) = utilized in proportion to its availability

TABLE 3
MEAN DENSITY OF TEAK AND OTHER FOOD PLANTS (TREES) OF GAUR IN PENCH TIGER RESERVE

	Mean density of trees/ha (S.E.)	
Teak		
Debarked plots	446.5 /ha	(±125.3)
Undebarked plots	157.5 /ha	(±125.6)
($t = 365.4$, d.f. $= 61$, $p<0.0001$)		
Food plants (trees) other than teak		
Debarked plots	112.48 /ha	(±46.1)
Undebarked plots	380.30 /ha	(±54.8)
($t = 540.3$, d.f. $= 61$, $p<0.0001$)		

TABLE 4
TEAK BARK MINERAL CONTENTS IN PENCH TIGER RESERVE (n=10)

Minerals	Range (ppm)	Mean (ppm)	S.E. ±
Ca	37,500-66,700	62,670.0	±4336.3
Na	400-750	590.0	±45.8
Fe	28-245	152.6	±18.7
Mn	19-26	20.0	±1.0
Cu	19-29	30.6	±5.5

1971). For the gaur, this may be one of the advantages of feeding on bark. The mineral contents of teak bark obtained from this study are similar to those reported by Tewari (1992) from other parts of central India. Teak bark being rich in protein and minerals, like calcium and sodium, would be beneficial to gaur. Requirement of minerals like calcium and phosphorus for ruminants ranges from 500 to 800 ppm and 300 to 450 ppm respectively (Webb 1988). The concentration of calcium in teak bark analyzed was 37,500-66,700 ppm. Tewari (1992) has also reported high concentration of calcium (22,400 ppm) and phosphorus (400 ppm) in the teak bark. Thus, consumption of teak bark would help the animal to satisfy its mineral needs and meet the food shortage to fulfil its physiological and nutritional requirements. High water content in the bark could be just an additional benefit to the animal in summer, when water becomes a limiting resource.

The results indicated that trees of different girth classes were debarked disproportionately to their availability. Such disproportionate use of resources can be termed as selective (Johnson 1980). Thus, high abundance of trees of one girth class did not necessarily result in high use. Areas with higher density of teak were preferred by gaur for debarking. The high tree availability perhaps provided better opportunities to feed selectively and reduced the time spent on searching. Also, by feeding in dense stands, the animals expend less energy per unit time (Curtis and Wilson 1943, Krebs and McCleery 1984). With the increase in the girth class of teak trees, the area debarked decreased i.e. the younger trees were debarked more than the older ones. This could be due to the fact that the bark of younger trees was softer and relatively less thick. Hence, it was easy for the gaur to strip the bark in large quantity and to reach the phloem and cambium layers that are rich in nutrients.

The bark consists of all tissues external to the vascular cambium (Esau 1967) and is composed of phloem, cortex, periderm, and remnants (if any) of the epidermis (Niklas 1999). The bark of a tree serves as a protective shield, insulating it against extremes of temperature, fire, desiccating wind, and against herbivory and microbial infections (Romberger *et. al.* 1992). Forest fire is known to affect the cambial tissue of trees (Uhl and Kauffman 1990, Hengst and Dawson 1993, Pinnard and Huffman 1997). During the study there were a few incidents of fire in the plots where debarking had taken place, but they were limited to the understory vegetation. No mortality of debarked trees was noticed as a result of the low intensity fire. Extensive damage caused by debarking is known to affect the radial growth of trees (Krefting *et. al.* 1962, Storm and Halverson 1967). In all debarked trees in the study area, the meristematic tissues of the stem grew over a period of time (6 months to 1 year) depending upon the intensity of debarking, and covered the exposed portion.

Incidents of debarking of teak by sambar (*Cervus unicolor*) were reported from Gir National Park, Gujarat (Khan *et al.* 1994), but in PTR, debarking of teak by wild ungulates other than gaur was not observed.

Since different nutrients tend to co-vary in their concentrations within plant tissues, depending upon the phenological stage of the plant (Westoby 1978), it is necessary to obtain the profile of the important minerals constituting teak bark at the different phenological stages of teak. This will give a clue as to why gaur debark teak trees only in summer. Moreover, as noted by Owen Smith and Novellie (1982), one of the factors which is rebuttal for foraging performance is the food quality. The availability of secondary compounds in different plants in varying degrees also limits their palatability (Freeland and Janzen 1974). Further analysis of the bark samples of teak and other food plants for secondary compounds and nutritional quality would provide insights into the debarking behaviour of gaur.

ACKNOWLEDGEMENTS

We thank the Madhya Pradesh Forest Department for permission to work in Pench on gaur. We thank Shri S.K. Mukherjee, Director, Wildlife Institute of India, for the support extended to the Gaur Ecology Project and Dr. J.A. Khan, Dr. Ravi Chellam, Dr. S.P. Goyal and Dr. Y.V. Jhala for their useful comments on the manuscript. We also thank our field assistants Gurhan and Guddu, for help in the fieldwork.

REFERENCES

ALLEN, D.L. (1943): Michigan fox squirrel management. Mich. Dept. Cons. Game Divn. Publ. No. 100: 1-404.

ALLEN, E.S. (1989): Chemical Analysis of ecological materials. 2nd Edn. Blackwell Scientific Publications, Oxford, U.K. Pp. 368.

BAX, P.N. & D.L.W. SHELDRIK (1963): Some preliminary observations on the food of elephants in the Tsavo Royal National Park (East) of Kenya. *E. Afr. Wildl. J. 1*: 40-53.

BELL, R.H.V. (1971): A grazing ecosystem in the Serengeti. *Sci. Am. 225*: 86-93.

BORGES, R.M. (1989): Resource heterogeneity and the foraging ecology of the Malabar giant squirrel (*Ratufa indica*). Ph.D. thesis, University of Miami, Florida. Pp. 221.

BRANDER, A.A.D. (1923): Wild animals in Central India. Arnold, London. Pp. 296.

CHAMPION, H.G. & S.K. SETH, (1968): A revised survey of the forest types of India. Manager of Publications, Government of India, New Delhi. Pp. 404.

CROZE, H. (1974): The seronera bull problem II. The trees. *E. Afr. Wildl. J. 12*: 29-47.

CUNNIF, P. (1995): Official methods of analysis of AOAC (Association of Official Analytical Chemists) International. Vol. 1. Virginia. AOAC International, Washington D.C. Pp. 684.

CURTIS, J.D. (1941): The silviculture significance of the porcupine. *J. For. 39*: 583-594.

CURTIS, J.D. & A.K. WILSON (1943): Porcupine feeding on Ponderosa pine in Central Idaho. *J. For. 51 (5)*: 339-341.

ESAU, K. (1967): Plant anatomy, 2nd Edn. John Wiley & Sons, New York. Pp. 767.

FOWLER, J. & L. COHEN (1986): Statistics for ornithologists. BTO Guide No. 22. British Trust for Ornithologists. Pp. 175.

FREELAND, W.J. & D.H. JANZEN (1974): Strategies in herbivory by mammals: The role of plant secondary compounds. *Amer. Nat. 108 (961)*: 269-289.

HENGST, G.E. & J.O. DAWSON (1993): Bark properties and fire resistance of selected tree species from the central hardwood region of North America. *Canadian J. of Forest Research 24*: 688-696.

JOHNSON, D.H. (1980): The comparison of usage and availability measurements for evaluating resource preference. *Ecology 61(1)*: 65-71.

JOSHUA, J. (1992): Ecology of endangered grizzled giant squirrel (*Ratufa macroura*) in Tamil Nadu, South India. Ph.D. Thesis. Bharathidasan University, Tamil Nadu, India. Pp. 131.

KENWARD, R.E. & T. PARISH (1986): Bark stripping by grey squirrels (*Sciurus carolinensis*). *J. Zool. 210*: 473-481.

KHAN, J.A., W.A. RODGERS, A.J.T. JOHNSINGH & P.K. MATHUR (1994): Tree and shrub mortality and debarking by sambar (*Cervus unicolor* Kerr) in Gir after a drought in Gujarat, India. *Biol. Conserv. 68*: 149-154.

KREBS, J.R. & R.N. MC CLEERY (1984): Optimization in Behavioural Ecology. Pp. 91-121. *In*: Behavioural Ecology — An Evolutionary Approach (Eds.: Krebs, J.R. & N.B. Davis). Blackwell Scientific Publications, London. Pp. 493.

KREFTING, L.W., J.H. STOECKER, B.J. BRADLE & W.D. FITZWATER (1962): Porcupine-timber relationship in the lake state. *J. For. 60*: 325-330.

LAWS, R.M., I.S.C. PARKER & R.C.B. JOHNSTONE (1975): Elephants and their habitats. Clarendon Press, Oxford. Pp. 376.

MCKAY, G.M. (1973): Behaviour and ecology of Asiatic elephant in southeastern Ceylon. Smithsonian Institution, Washington D.C. Pp. 13.

MacKinnon, K.S. (1976): Home range, feeding ecology and social behaviour of grey squirrel (*Sciurus carolinensis* Gmelin). D.Phil. Thesis. Oxford University (Original not referred).

Marcum, C. Les & Don D. Loftsgaarden (1980): A non-mapping technique for studying habitat preferences. *J. Wildl. Manage. 44 (4)*: 963-968.

Niklas, K.J. (1999): The mechanical role of bark. *Am. J. Botany 86(4)*: 465-469.

Ogilive, C.S. (1954): The behaviour of seiadang. *Malaya Nat. J. 9*: 1-10.

Owen-Smith, R.N. (1988): Megaherbivores: Influence of very large body size on ecology. Cambridge University Press, Cambridge. Pp. 369.

Owen-Smith, R.N. & P. Novellie (1982): What should a clever ungulate eat? *Amer. Nat. 119(2)*: 151-178.

Pinnard, M.A. & J. Huffman (1997): Fire resistance and bark properties of trees in seasonally dry forest in eastern Bolivia. *J. Tropical Ecology 13*: 727-740.

Prior, R. (1984): Trees and deer: How to cope with deer in forest, field and garden. B.T. Batsford, London. Pp. 208.

Ranjitsinh, M.K. (1997): Beyond the tiger: portraits of Asian wildlife. Brijvasi Printers. New Delhi. Pp. 208.

Romberger, J.A., Z. Hejnowicz & J.F. Hill (1992): Plant structure: Function and development. Springer-Verlag, Berlin. Pp. 524.

Schaller, G.B. (1967): The deer and the tiger. University of Chicago Press, Chicago. Pp. 370.

Sharma, D. & S.N. Prasad (1992): Tree debarking and habitat use by porcupine (*Hystrix indica* Kerr) in Sariska National Park in Western India. *Mammalia 56(3)*: 351-361.

Spinage, C. (1994): Elephants. T & A.D. Poyser Ltd. London. Pp. 319.

Storm, G.L. & C.H. Halverson (1967): Effect of injury by porcupines on radial growth of ponderosa pine. *J. For. 65*: 740-743.

Sukumar, R. (1989): The Asian Elephant: Ecology and Management. Cambridge University Press, Cambridge, UK. Pp. 215.

Sullivan, T.P. & D.S. Sullivan (1982): Bark damage by snowshoe hares and red squirrels in Lodge Pole pine stands in Central British Columbia. *Can. J. For. Res. 12*: 443-448.

Tewari, D.N. (1992): A monograph of teak (*Tectona grandis* Linn. f). International Book Distributors, Dehra Dun. Pp. 479.

Uhl, C. & J.B. Kauffman (1990): Deforestation, fire susceptibility and potential tree responses to fire in the eastern Amazon. *Ecology 71*: 436-499.

Vancuylenberg, B.W.B. (1977): Feeding behaviour of Asiatic elephant in southeast Sri Lanka in relation to conservation. *Biol. Conserv. 12*: 33-54.

Webb, R. (1988): A preliminary investigation into the fodder qualities of some trees in Sudan. *Int. Tree Crops J. 5*: 9-17.

Westoby, M. (1978): What are the biological bases of varied diets? *Amer. Nat. 112*: 627-631.

White, C.G. & R.A. Garrot (1990): Analysis of wildlife radio tracking data. Academic Press Inc., San Diego, USA. Pp. 83.

■ ■ ■